

Geotechnical Properties of Certain Iraqi Carbonate Rocks



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ABSTRACT

Petrography and some geotechnical properties of certain Iraqi carbonate rocks belonging to (8) geologic formations from (10) locations, were studied in lab.

The Influence of petrography and water saturation on the engineering properties was investigated. Correlation between different physical and mechanical properties was achieved.

Finally a proposed engineering classification based on (bulk density, porosity, compressional wave velocity, dynamic modulus of elasticity, uniaxial compressive strength and brazillian tensile strength) for the studied rocks was established.

It is concluded that the studied carbonate rocks can be divided into three main groups according to their physical and mechanical properties, they are namely (high strength, medium to high strength & low to medium strength) rocks.

Keywords: *Rock Mechanic, Limestone, Physical Properties, Dynamic Properties, Petrography, Water Saturation.*

Introduction

Carbonate rocks are widely common dispersed materials of Iraq, they form an important part of the Iraqi stratigraphic columns. Their outcrops covering large area of the mountainous region in Sulaimani, Erbil, Dohok, east of the Tigris from Mosul in the north to the south of Kfri and some regions west of Euphrates from Syrian border to south of Samawa[1].

Their availability makes these rocks be the widest foundation and construction material for most of the engineering projects.

What mentioned above make the study of the geotechnical properties of Carbonate rocks in Iraq of vital importance.

The study of the geotechnical properties of these rocks received little attention in Iraq. Most of the studies are restricted to certain local area, however few studies are found which can be regarded to be more than local, but none of them covered extensive area as achieved in the present study.

El- Rawi^[1] found a relationship between abrasion wear obtained in the Los Angeles abrasion test and each of compressive strength, Impact value & specific gravity of Iraqi limestone selected from (Ramadi, Karbala, Sulaimani & Mosul).

Fattohi & Youssif.^[2] suggested a model to estimate the strength values of Iraqi rocks involving (Sandstone, Marly Limestone and Limestone)

Al- Mahdawi^[3] studied the influence of specimen size and water saturation on the mechanical properties of Jeribe Limestone in Talafar (north Iraq).

Al-Assadi [4] Carried out a detailed engineering geological study to evaluate the foundation rocks of suggested location of Rawa- hydroelectric power station, whose rocks belonging to Baba and Ana Formations.

Dhanoon, & Al-Jubouri [5] studied the geotechnical properties of Al-Fatha & Pila Spi Limestone from Mosul area. As a result they suggested a proposal for using these rocks and to qualify the construction.

This paper is an attempt to study some geotechnical properties of Certain Iraqi Carbonate rocks as well as to make an engineering classification in addition to investigate the probable relationship between petrography and the engineering properties.

Sixty-eight core samples of (5.5 & 7.5Cm) diameter were obtained from (10) locations belonging to (8) stratigraphic

carbonate formations as shown in fig(1) and table (1).

Fourty-two thin sections were prepared from the obtained sample representing all formations and locations and studied petrographically under polarizing microscope.

Physical properties, including (bulk density, porosity and water absorption) were determined.

Ultrasonic compressional and shear wave velocities were measured from which dynamic modulus of elasticity was calculated for the whole samples.

Uniaxial compression test was performed on all core samples with (D/L ratio=1:2.5) from which uniaxial compressive strength and %50 tangent modulus of elasticity were determined.

Brazilian test was performed on disk samples of ((D/L) ratio=0.4) for indirect tensile strength determination.

The additional twenty core samples were saturated with water according to a procedure followed by [6,3,7] to obtain (nearly %100 water saturation), then both compressional wave velocity measurement & uniaxial compression test were achieved.

All the above mentioned physical and mechanical tests were performed according to (ASTM)⁽⁸⁾⁽⁹⁾, (ISRM)⁽¹⁰⁾⁽¹¹⁾.

Petrography:

For microscopic study of the samples at least two thin sections are made for each ones. The polarizer microscope is used for identification of textures & components.

Based on Dunham^[12] & Folk^[13] the involved carbonate rocks are classified using point counting.

The calculated percentage are divided into two main groups, the first one regarded as depositional component such as, matrix and allochems (grains), the second one are those component formed by diagenesis, such as, sparite, dolomite and secondary porosity (fracture and solution porosity), plate(1-,2).

The most abundant components are grains and matrix, forming > %60 of most samples.



Fig.(1)Location map of the studied rocks

The sparite and dolomite grains, as a diagenetic component are less abundant and form <%30 of the counted points. (table. 2).

It is obvious that all engineering and physical properties of rocks are attributed to properties derived from microscopic constituents.

Unfortunately, in most cases, the original grains and matrixes of the carbonate rocks are modified by diagenetic processes. These include solution, cementation, compaction and dolomitization.

All these cause essential change of the rock texture, physical, chemical and engineering properties of the rocks.

The negative role, in most cases of solution and dolomitization, is destroying internal microscopic support that exists between the grain or may remove the matrix that bind the grains together.

In contrast to negative effect of diagenesis, there are positive ones, mainly including cementation and compaction which both filling the depositional interparticle pores (voids), thus reducing porosity and finally make the carbonate rock to behave as indurate, compact and hard engineering materials.

The duration of geologic time is also affecting positively the engineering properties of materials by increasing both compaction and cementation. That is why Qamchuqa, Bekhma and Kometan rocks have higher and better properties than most of the younger ones, such as Jeribe, Fatha and Pila Spi rocks.

The matrix as a binding material and rock constituents include all grains that are less than 30micron in diameter, but allochems (grains) are those grains which are more than 30 micron in diameter.

In all studied samples fossil skeleton and fragments make up more than %60 of the rock. The most abundant fossil are Foraminifera, Gastropods and Pelecypods with few green and red algae.(plate-1-2,3,6)

Table (1): Location of the studied samples

Sample No.	Geologic Formation	Age	Location	Remarks
Q1	Qamchuqa	Hautrivian-Albian	Bekhma Damsite/ Erbil	Core samples
Q2	Qamchuqa	Hautrivian-Albian	Shaqalawa /Erbil	Block/ out crop.
B1	Bekhma	Late Campanian-Maastrichtian	Bekhma Damsite/ Erbil	Core samples
B2	Bekhma	Late Campanian-Maastrichtian	Shaqalawa /Erbil	Block/ out crop.
S1	Sinjar	Upper paleocene-Lower Eocene	Tasluja/ Sulaimani	Block/ out crop.
S2	Sinjar	Upper paleocene-Lower Eocene	Derbendikhan/ Sulaimani	Block/ out crop.
E1	Euphrates	Early Late Miocene-Early Middle Miocene	Rawa Bridge/ Rawa	Core samples
E2	Euphrates	Early Late Miocene-Early Middle Miocene	Rawa Bridge/ Rawa	Core samples
K1	Kometan	Lower Turonian- Santonian	Dokam Dam/ Sulaimani	Core samples
K2	Kometan	Lower Turonian- Santonian	Sarchinar/ Sulaimani	Block/ out crop.
P1	Pila Spi	Middle Miocene-Upper Eocene	Derbendikhan/ Sulaimani	Block/ out crop.
P2	Pila Spi	Middle Miocene-Upper Eocene	Bazian/ Sulaimani	Block/ out crop.
F1	Al-Fatha	Middle Miocene	Saddam Dam site/ Mosul	Core samples
F2	Al-Fatha	Middle Miocene	Saddam Dam site/ Mosul	Core samples
J1	Jeribe	Middle Miocene	Saddam Dam site/ Mosul	Core samples
J2	Jeribe	Middle Miocene	Talafer / Mosul	Block/ out crop.

Geotechnical Properties

Several considerable variation can be recognized in the values of the geotechnical properties of the studied carbonate rocks. (Table 3).

Generally ,bulk density ranges between (2.07 and 2.52 gm/cc). Qamchuqa and Bekhma rocks are characterized by highest values, while Kometan , Fatha and Jeribe rocks show the lowest one , may be due to the difference in porosity (%2.7-14.3%), possibly as a result of variation in intensity of diagenesis, Such as, compaction, cementation and solution processes.

Several previous studies mentioned that the oldest carbonate rocks are characterized by high density and low porosity , as revealed from the study of (14) on Ordovician carbonate rocks and that of (15) on the Carboniferous carbonate rocks, while others inferred low density and high porosity, who worked on younger carbonate

rocks, such as (16) on the Egyptian Eocene carbonate rocks and (3)(4)(5) on the Iraqi carbonate rocks of Tertiary age.

The effect of geologic time span is returned to the fact that, the oldest rocks are commonly subjected to greater compaction and to longer duration of Cementation than the younger one.

A acceptable correlation value ($r = 0.70$), is found between porosity and uniaxial compressive strength, table (4), as well as, an empirical exponential equation with ($r = 0.73$) is extrapolated to estimate uniaxial compressive strength from porosity. table (5), consequently, porosity can be considered as one of the important parameters for the engineering classification of the studied carbonate rocks.

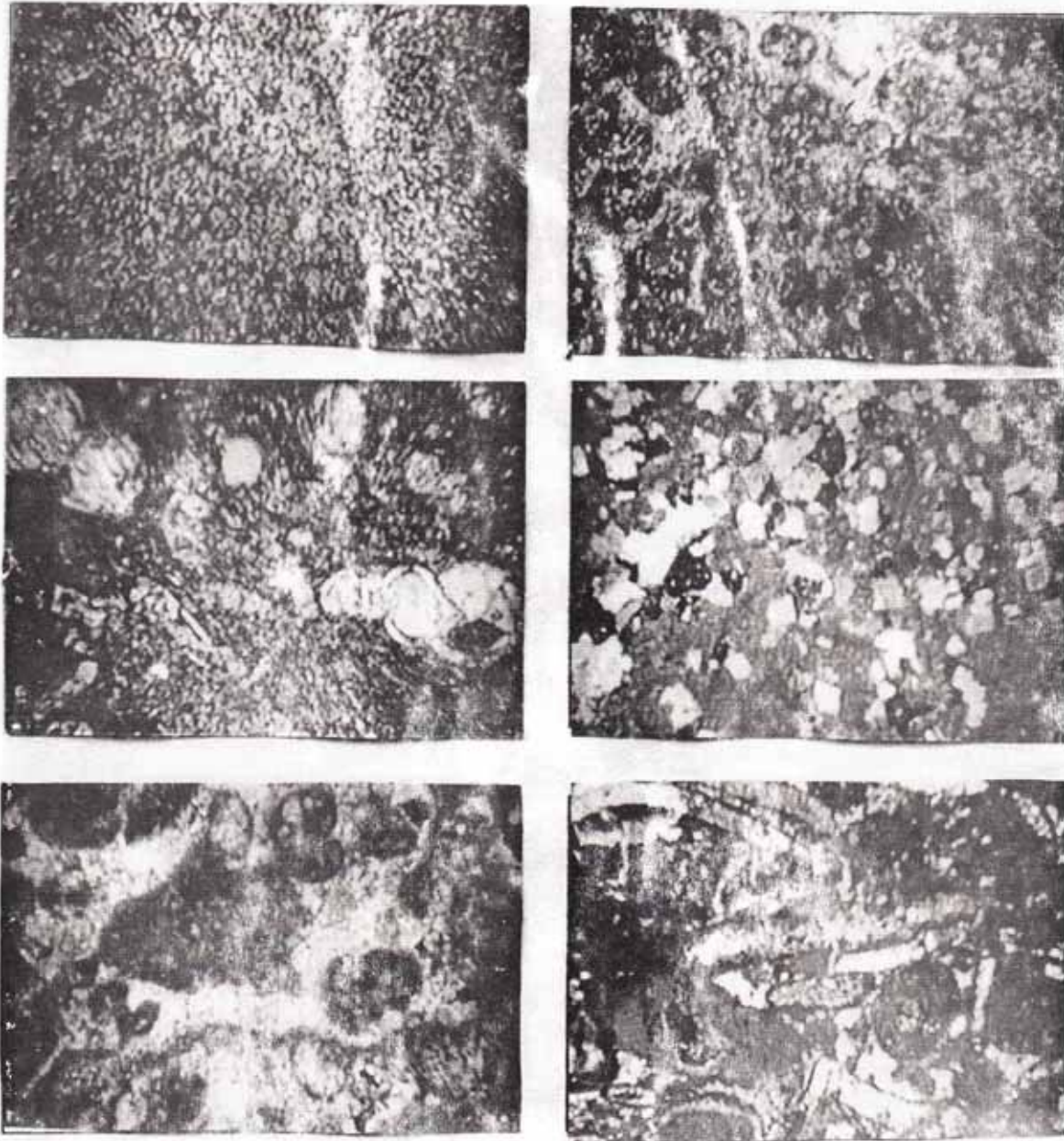


Plate (1)

1. Mudstone (S.No.Q1)-(PPL-X50)
2. Planktonic Wackstone (S.No.K1)-(PPL-X100)
3. Bioclast Packstone (S.No.S1)-(PPL-X25)
4. Dolomitized Boundstone (S.No.E2)-(PPL-X25)
5. Recrystallised Dolostone (S.No.F2)-(PPL-X50)
6. Bioclast Packstone (S.No.S2)-(PPL-X25)



Plate (2)

1. Leached wackstone (S.No.F1) (PPL X25)
2. Recrystallised wackstone (S.No.E1) (PPL X 50)
3. Recrystallised wackstone (S.No.E1) (PPL X 50)
4. Leached chalky Limestone (S.No.P2) (PPL X50)
5. Leached Mudstone (S.No.J2) (PPL X50)
6. Planktonic wackstone (S.No.K2) (PPL X100)
7. Leach chalky L.st (S.No.P2) (PPL X50)
8. Sandy wackstone (S.No.82) (PPL X50)

Rodríguez [17] made two Correlations of uniaxial compressive strength with porosity, one for porous carbonate rocks and another for those that are fissured but of low porosity, he Concluded that carbonate rocks with <3% porosity present a remarkable range in compressive strength and best correlation between porosity and strength are found in rocks of porosity >4%.

In spite of the great importance of water absorption in carbonate rocks, especially, when it is used as building stone or aggregates, water absorption of the studied carbonate rocks were determined and correlated with other engineering properties, but without more details for it is not the essence of this work. However water absorption show good Correlation ($r=0.64, 0.68$) with each of bulk density and porosity respectively.

A remarkable variation can also be observed in the ultrasonic wave velocities of studied rocks, where the older micritic carbonates (Qamchuqa and Bekhma) show the highest value relatively to younger ones of different texture and lithology, most probably due to differences in isotropy, texture and in some manner to porosity, which has a weak relation with compressional and shear wave velocity (0.47 and 0.34) respectively.

Table (4), indicates that the best correlation is detected between each of compressional wave velocity and the calculated dynamic modulus of elasticity with both uniaxial compressive strength and tensile strength, which can be commonly returned to the influence of texture^{[5][8]}.

Table (2): The result of the Microscopic study of the studied samples.
(Each sample representing at least study of 2 thin section)

S.N.	% Sparite	% Matrix	% Allochems	% Voids	% Dolomite	Suggested Name according to Dunham (1962) + Flok (1959) between brackets
Q1	5	50	12	3	30	Mudstone (Micritic L.st)
Q2	5	40	10	12	33	Mudstone (Micritic L.st)
B1	10	55	20	5	10	Mudstone (Micritic L.st)
B2	5	75	10	5	5	Sandy Wackstone (Spars sandy Micritic L.st)
S1	5	50	40	5	0	Bioclast Packstone (Packed Biomicritic)
S2	3	45	45	7	0	Bioclast Packstone (Packed Biomicritic)
E1	20	20	40	5	15	Recrystallized Wackstone (Recryst. Spars Micritic)
E2	15	10	300	10	35	Dolomitized Bound stone (Biolucite)
K1	10	60	20	3	7	Planktonic wackstone (Form. Spars Biomicritic)
K2	10	70	10	3	7	Foraminiferal wackstone (Form. Spars Biomicritic)
P1	10	80	0	10	0	Chalky L.st (Micritic L.st)
P2	10	72	0	18	0	Leached Chalky L.st (Leached Micritic L.st)
F1	5	60	15	20	0	leached wackstone (Leached spars Micritic L.st)
F2	30	15	0	5	50	Dolostone (Dolostone)
J1	30	20	40	10	0	Bioclast Packstone (Packed Biomicritic)
J2	5	50	10	30	5	Leached Mudstone (Leached Micritic L.st)

The best empirical equations for estimating uniaxial compressive strength and tensile strength are illustrated in table (5).

Accordingly, compressional wave velocity and dynamic modulus of elasticity, can be utilized as a bases for engineering classification of carbonate rocks.

Many authors used compressional wave velocity for compressive strength estimation of rocks, such as [18], [19] & [20].

The results of the uniaxial compression test on core samples of the studied rocks are illustrated in table (3) and fig. (2).

Table (3): Physicomechanical properties of the studied carbonate rocks

Sample index	Name	Physical properties						Mechanical properties			
		Bulk density gm/cc	Porosity %	Water absorption %	Compressional wave velocity Km/sec	Shear wave velocity km/sec	Dynamic modulus of Elasticity MN/m ² x10 ³	Static modulus of Elasticity MN/m ² x10 ³	Compressive strength MN/m ²	Tensile strength MN/m ²	Modulus Ratio
Q1	Mudstone	2.48	4.7	3.2	5.81	2.93	56.54	7.24	91.5	8.6	79.12
Q2	Mudstone	2.4	6.5	4.9	5.93	3.03	58.26	10.41	77	6.7	135
B1	Mudstone	2.52	2.7	1.4	5.16	2.712	48.5	5.25	79	8.1	66.45
B2	Sandy wackestone	2.48	3.1	4.5	5.42	2.803	51.18	7.14	82.5	7.8	86.3
E1	Recrystallized wackestone	2.15	9.7	13.2	5.091	2.885	44.95	4.38	57.5	7.2	76.17
E2	Dolomitized Boundstone	2.25	8	12.9	5.38	2.26	32.2	5.2	64	7.5	81.25
S1	Bioclast Packstone	2.31	6.3	7.3	4.902	2.47	37.39	5.2	55	5.9	94.5
S2	Bioclast Packstone	2.24	5.7	5.2	4.68	2.52	36.94	6.94	51	4.2	136
K1	Planktonic wackestone	2.11	9.6	8.2	4.878	2.61	37.29	4.76	46	4.1	103.47
K2	Foraminiferal wackestone	2.13	7.3	7.8	4.625	2.386	31.93	4.5	43	5.7	104.65
P1	Chalky Limestone	2.14	10.1	8.2	3.685	2.028	22.73	5.2	30	3.2	173
P2	Leached Chalky Limestone	2.18	7	9.2	3.732	2.028	23.17	3.7	33	2.8	112.12
F1	Leached Wackestone	2.1	10.9	12.9	4.16	2.39	30.11	4.25	24	2.2	177
F2	Coarse grain Dolostone	2.07	10.2	10.4	3.9	2.31	27.11	4.16	32	2.4	130
J1	Bioclast Packstone	2.09	14.3	13.2	3.65	2.11	24.65	2	18	2.3	111.11
J2	Leached Mudstone	2.01	11.4	15	3.32	1.85	17.48	1.38	22	2.4	62.7

At different stress levels, strains were calculated from the over all axial deformation using dial gauges of (0.001mm accuracy) till failure.

The plotted stress-strain curves (fig.2), show that the deformation behavior of carbonate rocks are varying between those behaving more elastically, and those passing through a variable plastic deformation prior to failure.

It is observed that, Bekhma, Qamchuqa rocks relatively behave elastically up to a range of (%81 - %97) of the ultimate strength, after that starting to deform plastically till rupture, whereas (Euphrates, Kometan and Sinjar) rocks exhibit plastic deformation at a stress level (%81 - %89) of the ultimate strength, but the plastic portion of (Jeribe, Pila Spi and Fatha) rocks fall at the range of (%74.5-%83.5) of the ultimate strength.

This variation in deformation characteristics probably related to the variation in texture from micritic (mudstone), with fine grains which behave more elastically to bioclast packstone (packed biomicrite) that deform more elastoplastically^{[15][21]}, with some consideration that should be given to the chalky nature of Pila Spi rocks that deform more plastically, with few exceptions to Fatha rocks (F₂) of the dolomitic nature which behave elastically^[15].

The %50 tangent modulus of elasticity calculated from the stress - strain curves, shows relatively weak relationship with other engineering properties, as a reflection of the interaction between porosity, texture and mineralogy factors. This weak relationship of static modulus of elasticity with other physical properties, particularly

with strength properties, make this parameter and modulus ratio be not suitable for the engineering classification of carbonate rocks. Fig.(3-d).

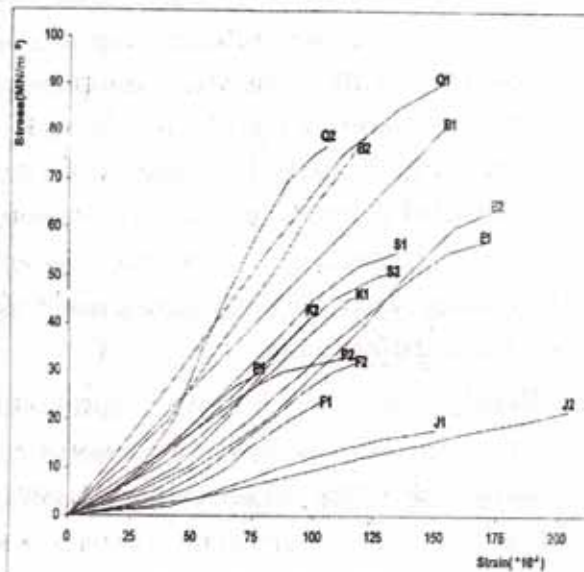


Fig (2) Stress-Strain curves of the studied rocks(Air dried)

An investigation of the available literature, combined with measurements made in this work, indicate that there is great variations between deformations measured by dial gauges (overall axial deformation) and those obtained from resistance strain gauges (mid height deformation), which consequently leads to appreciable differences in the magnitude of the calculated static modulus of elasticity for the same rock type^[22]. This is seems to be clearly approved from the Iraqi works on limestone^{[2][3][4][23]}. What is mentioned above is considered as another reliable reason for departing the static modulus of elasticity as a dependent parameter in the engineering classification of carbonate rocks.

The proposed engineering classification

As a result of the geotechnical study of the carbonate rocks, and from the relationship of the different engineering parameters with uniaxial compressive strength as shown in figs.(3-a,b,c,e & f). It is obvious that the studied carbonate rocks can be classified generally into three engineering groups, (Qamchuqa, Bekhma) group, (Euphrates, Sinjar, Kometan) group and (Pila Spi, Fatha, Jeribe) group.

Based on the above mentioned relationships and groups, an engineering classification of the studied carbonate rocks, depending on (uniaxial compressive strength, tensile strength, compressional wave velocity, dynamic modulus of elasticity, porosity & bulk density) is proposed as shown in table (6). Accordingly, the studied carbonate rocks are classified as (high strength), (medium- high strength) and (low – medium strength) rocks.

Influence of water saturation

The influence of water saturation on the (compressional wave velocity, uniaxial compressive strength, tangent modulus of elasticity as well as deformation behavior) of some studied carbonate rocks was performed and the results are clarified in table (7) and figs. (4, 5 & 6).

Generally, saturating of the core samples with water, was found to result in an irregular increase in the compressional wave

velocity of the carbonate rocks by (%0.083 - %7.73) with respect to dry condition, except rock samples of (S1 & J1), which show a reduction in velocity with saturation by (%1.36 & %1.64) respectively.

This irregularity in the effect, can be attributed to the orientation of the rock constituents (voids and grains), as well as to the differences in rock strengths, where the stronger rocks and minerals show less reaction to saturation than the weaker ones. The type of the pore system (open or close system) may have its influence to a certain extent ^[24].

This result is in contradiction with those obtained by several other investigators and compatible with others, which can be attributed to the method of velocity measurements and the frequency range applied during the test ^[24], as well as to the method followed for saturation.

Generally the strong rocks such as (Qamchuqa and Bekhma) weakly affected by saturation, while (Pila Spi) due to their chalky nature hardly affected, and Fatha (F2) due to the high percent of dolomite (%50) is weakly affected.

The effect of water saturation on the strength and deformation properties of carbonate rocks is more clear and obvious than its effect on the compressional wave velocity.

Table (4) correlation coefficient between different physico-mechanical properties.

		1	2	3	4	5	6	7	8	9
1	Bulk density (γ)	1	0.77	0.64	0.60	0.48	0.70	0.51	0.84	0.68
2	Porosity (n)		1	0.68	0.47	0.34	0.48	0.43	0.70	0.56
3	Water absorption (w)			1	0.30	0.35	0.46	0.49	0.49	0.30
4	Comp. Wave velocity (Vp)				1	0.79	0.86	0.64	0.86	0.81
5	Shear wave velocity (Vs)					1	0.93	0.58	0.68	0.59
6	Dyn. Modulus of elasticity (Ed)						1	0.66	0.84	0.69
7	Static modulus of elasticity (Es)							1	0.58	0.36
8	Uncon. Comp. Strength (σ_c)								1	0.89
9	Tensile strength (σ_t)									1

Straiten leads to the reducing of the uniaxial compressive strength by different rates. Stronger rocks such as (Qamchuqa and Bekhma groups), show less influence (%10.38 and %8.86 respectively) than the other two groups, whose uniaxial compressive strengths reduced by (%26.08 to %38.8) with respect to dry condition, Fig (4-f).

The reliable probable reason for this reduction, are discussed and presented by several investigators such as [3] [6] [7] [21].

It is noticed from Figs. (5,6, 7) that the effect of water saturation on the deformation behavior of the studied rocks, followed the same pattern of its effect on strength properties through the three mentioned groups. With saturation the plastic region (Prior to failure) of the most the rocks increased.

This increase is seems to be more for the (Pila Spi, Fatha, Jeribe) group, but less for (Qamchuqa, Bekhma) group, due to the reasons mentioned before.

Table (5) the best empirical equations between some of the physico-mechanical properties.

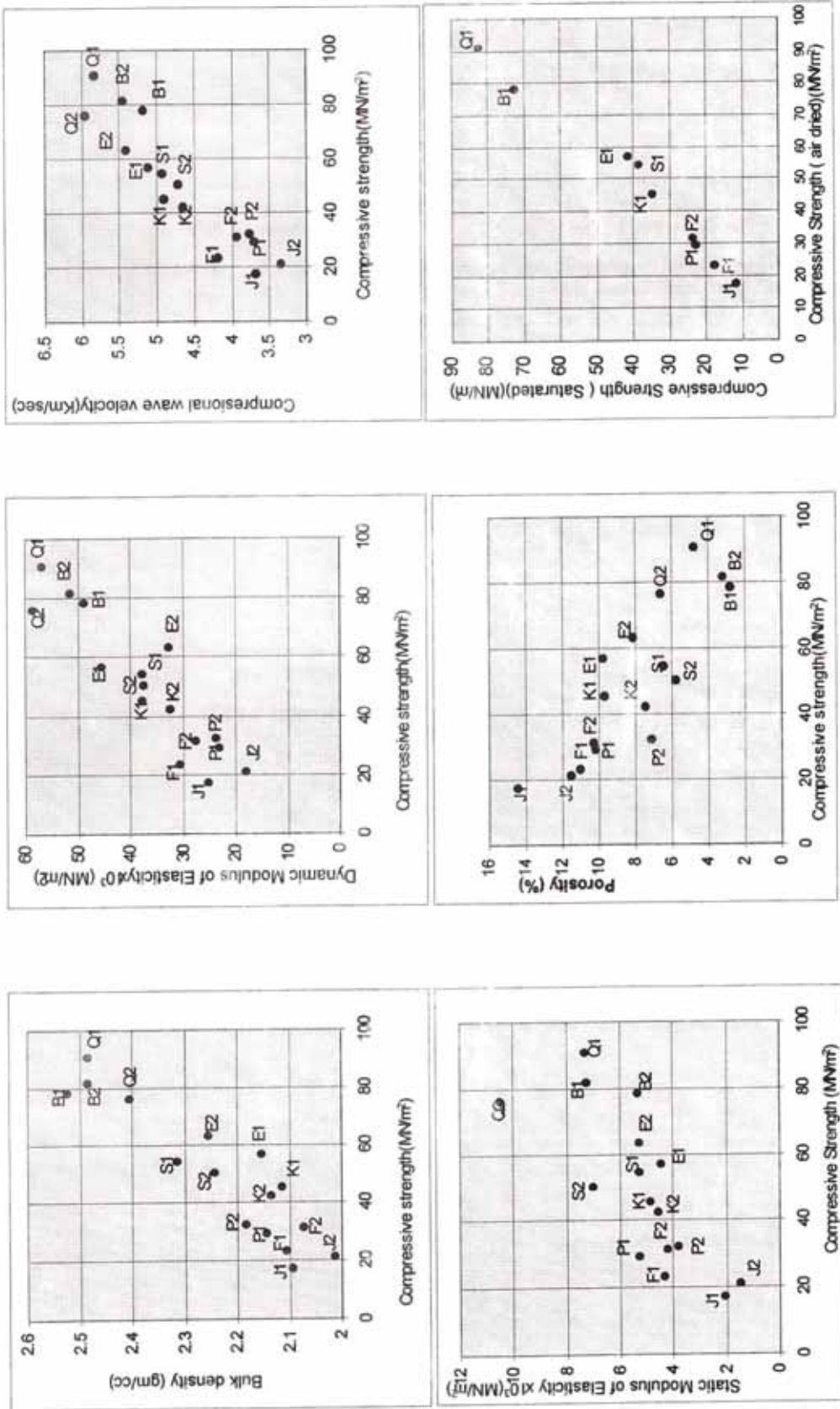
Parameters	Correlation coefficient	Empirical equation
(γ) and (n)	-0.82	$n = 2313.7 e^{-2.58 \gamma}$
(γ) and (Ed)	0.70	$Ed = (146.7 \ln \gamma - 80.94) \times 10^3$
(γ) and (σ_c)	0.74	$(\sigma_c) = 0.114 e^{2.68 \gamma}$
(γ) and (σ_t)	0.68	$(\sigma_t) = 27.35 \ln \gamma - 16.79$
(n) and (σ_c)	-0.73	$(\sigma_c) = 134.91 e^{-0.137/n}$
(Vp) and (Vs)	0.80	$(Vs) = 1.74 \ln Vp - 0.20$
(Vp) and (Ed)	0.88	$Ed = (5.16 e^{0.407 Vp}) \times 10^3$
(Vp) and (Es)	0.64	$Es = (2.1 Vp - 4.64) \times 10^3$
(Vp) and (σ_c)	0.87	$(\sigma_c) = 3.066 e^{0.578 Vp}$
(Vp) and (σ_t)	0.82	$(\sigma_t) = 0.32 e^{5.68 Vp}$
(Vs) and (Ed)	0.95	$Ed = 3107 e^{0.97 Vs}$
(Ed) and (Es)	0.66	$Est = 0.139 Ed + 0.061$
(Ed) and (σ_c)	0.84	$(\sigma_c) = (1.71 Ed - 12.02) \times 10^3$
(Ed) and (σ_t)	0.69	$(\sigma_t) = (0.157 Ed - 0.65) \times 10^3$
(σ_c) and (σ_t)	0.89	$(\sigma_t) = 0.095 (\sigma_c) + 0.26$

Table (6) The Proposed engineering classification of the Iraqi Carbonate rocks.

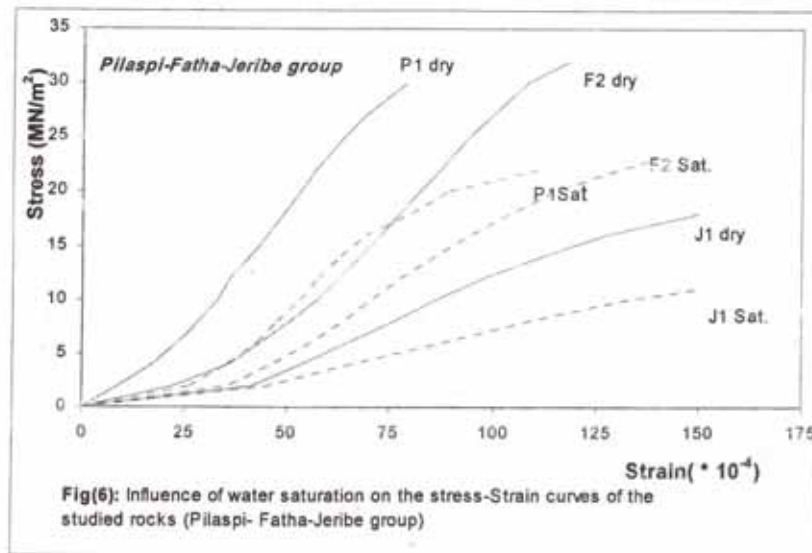
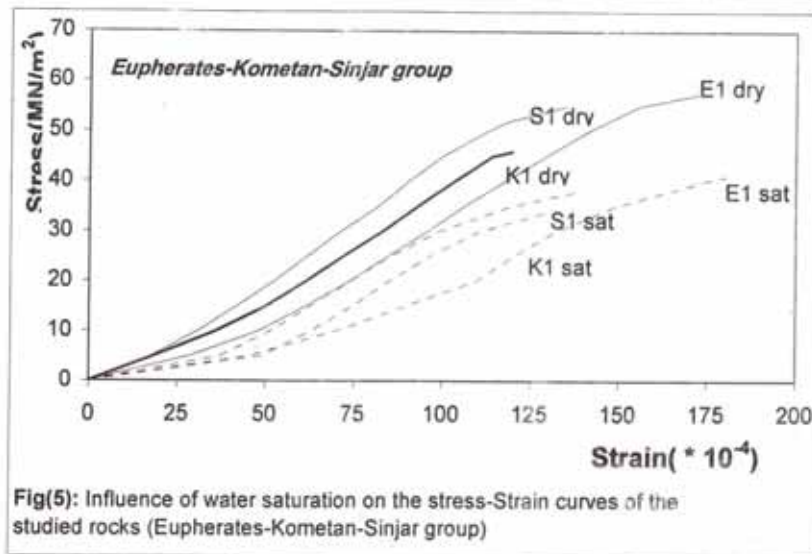
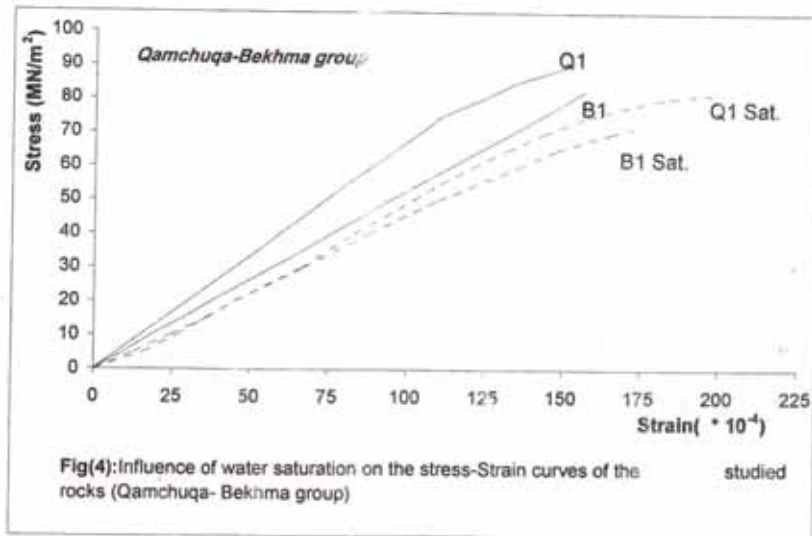
Bulk density gm / cc	Porosity %	Comp. Wave Velocity km/ Sec	Dyn Modulus of elasticity $MN/m^2 \times 10^3$	Uni. Comp. Strength MN/m^2	Tensile strength MN/m^2	Eng. Description
< 2.1	> 15	< 3.5	< 20	< 20	< 2	Low strength
2.1 – 2.25	10 – 15	3.5 – 4.5	20 – 30	20 – 40	2 – 4	Low- med. Strength
2.25 – 2.40	5 – 10	4.5 – 5	30 – 45	40 – 60	4 – 7.5	Med- high strength
> 2.40	< 5	> 5	> 45	> 60	> 7.5	High strength

Table (7): Influence of water saturation on (VP, σ_c , Etangent) of some studied carbonate rocks

Sample No.	Compressional wave velocity (Vp) (Km/sec)			Uniaxial compressive strength (σ_c) MN/m^2			Tangent modulus of Elasticity, $MN/m^2 \times 10^3$		
	Air dried	Saturated	% of change with respect to dry condition	air dried	Saturated	% of reduction with respect to dry condition	air dried	saturated	% of reduction
Q1	5.81	5.945	%2.32	91.5	82	%10.38	7.24	5.26	%27.34
B1	5.16	5.3	%2.71	79	72	%8.86	5.24	4.54	%13.52
E1	5.091	5.32	%4.30	57.5	41	%28.69	4.54	3.7	%18.5
S1	4.902	4.835	%1.36	55	38	%30.9	5.26	4.16	%20.91
K1	4.878	5.12	%4.96	46	34	%26.08	4.76	3.57	%25
P1	3.685	3.97	%7.73	30	22	%26.66	5.2	4	%23.07
F1	4.16	4.35	%4.56	24	17	%29.16	4.25	2.5	%41.17
F2	3.9	3.88	%0.083	32	23	%28.12	4.16	2.63	%36.77
J1	3.65	3.59	%1.64	18	11	%38.8	2	0.9	%55



Fig(3): Uniaxial compressive strength (air dried) versus (a) bulk density (b) dynamic modulus of elasticity (c) compressional wave velocity (d) static modulus of elasticity (e) porosity (f) uniaxial compressive strength (saturated).



Conclusion

- 1- petrographically, the studied carbonate rocks are classified as (Mudstone, Wackstone, Bioclast packstone, Recrystallised wackstone, Dolomitized boundstone, Dolostone & Chalky limestone).
- 2- Duration of time seems to be an important factor in improving geotechnical properties of the carbonate rocks, by increasing compaction and cementation.
- 3- Statistically, acceptable correlation values was found between (Bulk density, porosity, compressional wave velocity and dynamic modulus of elasticity) with each of uniaxial compressive strength and tensile strength, accordingly they considered as suitable basis for engineering classification of carbonate rocks.
- 4- Static modulus of elasticity, shows weak relationship with most of the engineering properties, so it is not included as reliable factor for engineering classification.
- 5- Geotechnically, based on a proposed engineering classification, the studied carbonate rocks are grouped as (high strength, med- high strength and low-med strength) rocks.
- 6- Water saturation, show unclear effect on the measured compressional wave velocities of the samples, but as it was expected the compressive strength and modulus of elasticity considerably is reduced due to saturation by (%8.86 - %38.8) & (%13.52 - %55) in compare to dry condition respectively. The low reduction percentages are returned to high strength rocks while the higher ones are belonging to (med - high strength) rocks.

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رهوشته جيوتكنيكيه كانى هه نديك بهردى كاربوناتى عيراقى

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پوخته

رهوشته بهردينيه كان و جيوتكنيكيه كانى هه نديك بهردى كاربوناتى عيراقى كه هه لىبزاردهى (A) پيكهاتهى جيولوجى و له (10) ناوچهى جياجياى عيراقدا وهگر ابوون دهستنيشان كرا.

كارىگهري رهوشته بهردينيه كان و تيربوون به ناو له سه رهوشته نه ندىازياريه كان ليكولرايه وه، به يوه ندى نيوان رهوشته فيزياوى و ميكانيكيه كان له گه ل به كتريدا ديارى كرا.

به پشت بهستن به رهوشته كانى (چرى قه بارهيمى و ريزه كون و خيرايى شه پولى په ستانى، هاوكولكهى نيلاستيكي جوليهي، به رهه لستى په ستانى يه ك ته وه رهيمى و به رهه لستى راكيشانى به رزايلى) پوليونيكي نه ندىازيارى به شنيار كرا بؤ بهردى كاربوناتى له عيراقدا.

نه نجامه كانى نه م تويزينه وهيمه دهرى خست كه نه م بهرده كاربوناتيانه ددهوانرئيت بكرين به (2) گروه وه به پيى رهوشته فيزياوى و ميكانيكيه كانى، نه وان هس (بهردى به رهه لستى بهرز، بهردى به رهه لستى ناوه ندى بؤ بهرز له گه ل بهردى به رهه لستى نزم بؤ ناوه ندى).

الخواص الجيوتكنيكية لبعض الصخور الكربوناتيية العراقية

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الخلاصة

تم دراسة الخواص البتروغرافية و الجيوتكنيكية لبعض من الصخور الكربوناتيية العراقية في المختبر العائدة لثمان (8) تكاوين جيولوجية مختارة من عشرة (10) مواقع مختلفة.

كما تم دراسة تأثير البتروغرافي و التشبع المائي على الصفات الهندسية، كذلك تم ايجاد علاقات بين مختلف الخواص الفيزياوية و الميكانيكية.

اعتمادا على (الكثافة الكلية، المسامية، سرعة الموجات الانضغاطية، معامل المرونة الديناميكي، المقاومة الانضغاطية احادية المحور و المقاومة الشدية البرازيلية) تم اقتراح تصنيف هندسي خاص بالصخور الكربوناتيية العراقية.

نتيجة لهذه الدراسة و حسب التصنيف المقترح انفة الذكر و استنادا على ذلك تم تقسيم الصخور الكربوناتيية قيد الدراسة الى ثلاث مجاميع وهي (صخور ذات مقاومة عالية، صخور ذات مقاومة متوسطة - عالية، صخور ذات مقاومة واطنة - متوسطة).

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